Space Weather Technical Forecast

Issued on Thursday, 23 March 2023 at 13:02 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: G1 Minor Geomagnetic Storm Likely from imminent CME and/or fast wind arrivals. Daily Chance of R1/R2 Radio Blackouts. Active electron fluence increasingly Likely.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the past 24 hours, with X-ray activity at GOES16 peaking with a C2.6 at 22/1957UTC from AR3256 in the southeast disc, else following a decreasing trend in both cadence and level of flares. There are currently up to six sunspot regions on the disc, with AR3261 having departed the front-side over the southwestern limb in the period.

Nominally the largest and most complex region on the Earth-facing side is now AR3256 near the south-centre, which is currently manifesting as an Fho/Beta-Delta. The Mt Wilson delta spot candidate lies in the proliferating trailing region of the sunspot group, and comprises potentially at least a pair of mismatched polarities within one tenuous penumbra. While on paper a simpler region, AR3260 in the northeast was the only other sunspot to show a growing trend in the 24 hours, with trailer proliferation also evident as it became a Cho/Beta. To the east of this group, a small unipolar region developed from plage (yet to attain a number), while all other regions were stable.

A large filament currently circumscribes a large part of the northern crown on the front side, however this remains stable at the time of writing. The only Coronal Mass Ejection (CME) candidates seen on available imagery in the period have either been well to the east of the Sun-Earth line, else low-latitude and far-sided, all to no expected effect at Earth.

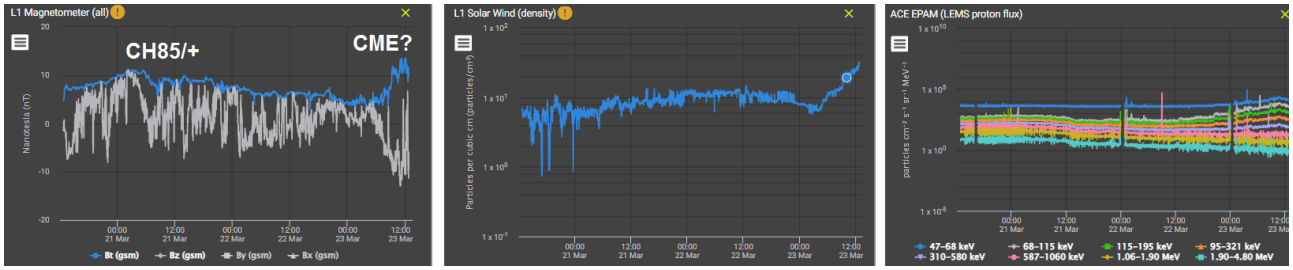

Figure 0: Three three-day measures of L1 solar wind, showing current enhancement in Bt and Bz at DSCOVR (left); density at DSCOVR, centre; and ACE EPAM LEMS, right.

Solar Wind / Geomagnetic Activity: The solar wind, as measured at L1 by DSCOVR and ACE, was initially reflective of gradual easing of a fast wind regime, likely to be that from CH85/+ given the predominantly positive phi angle (away from the Sun). This gave way to a CIR or CME-like rising density and IMF, with this new behaviour nominally beginning from around 23/0600UTC. At the time of writing, it is not yet clear as to whether this event comprises one of the outstanding 20 March CMEs, else the anticipated CH86/- CIR, or perhaps a combination of some or all of the above. STEREO A MAG and PLASTIC data is patchy, but otherwise similar as of 23/0200UTC to Earth conditions. Given that there should now be a day's lead-time for periodic solar wind

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enhancements and the fact that STEREO is east of Earth, perhaps means that the northeast-heading 20 March filament CME may be the main cause, although this remains to be seen in the coming hours.

The solar wind initially fell from Elevated levels near 525km/s, reaching 450km/s before a late rally to near 500km/s once again. The solar wind density fell from around 10ppcc to single figures for a time, undergoing a late increase to approach 25ppcc by the period's end. The ACE EPAM LEMS showed a similar sustained rise through the low-energy end of the proton spectrum into the current UTC morning. The IMF was mainly stable and at background levels until after 23/0600UTC, whereupon a rise to 13nT took place, with the north-south component strongly anti-aligned with Earth's field in reaching -13nT, with the co-aligned peak only +6nT.

The net result of the above solar wind measures was a provisional increase from Quiet geomagnetic activity, reaching a late peak of Kp 4+ in the 09-12UTC interval.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 is now close to Background levels.

The high energy electron flux (greater than 2MeV) has diurnally fluctuated between Normal Background and Moderate levels, with peak flux of 519pfu at 22/1550UTC. The associated 24-hour Electron fluence remained below the Active (1e8 integrated pfu) threshold, but with a rising trend. At 23/0001UTC the observed fluence was 1.4e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Generally Low Solar activity is expected, with a daily Chance of isolated Moderate flares, mainly from AR3256 or from one of several returning regions due onto the disc form the far-side in the period.

Solar Wind / Geomagnetic Activity: Two CMEs feature in the forecast - one overdue and one nominally imminent. They may have combined en-route. The sources of these are: firstly, a coronal dimming off the southwest disc on 20 March (now overdue); and secondly, a northeast filament eruption on 20 March due imminently.

The forecast otherwise comprises imminent exit from the mature fast wind of CH85/+ and the lapse into a second Elevated or Strong fast wind from CH86/- later on day 1 (Thursday 23 March), potentially preceded by a notable CIR region, and potentially bolstered by the outstanding CMEs. Elevated winds are then expected to continue for much of the rest of the period.

During day 1 (Thursday 23 March), the combined effect of CME arrival(s) and CH86/- enhancement is Likely to increase activity to G1/Minor Storm intervals, with a Chance of G2/Moderate storms given suitable alignment. Any enhanced activity is likely to continue day 2 (Friday 24 March), but gradually ease back to mainly Quiet to Unsettled levels from day 3 (Saturday 25 March).

Energetic Particles / Solar Radiation: High energy (greater than 10MeV) proton flux is expected to continue close to Background, with only a Slight Chance of further enhancements should any significant flares occur.

The high energy (greater than 2 MeV) electron flux is expected to rise day 2 (Friday 24 March) to Moderate and then High by day 3 (Saturday 25 March) in response to the enhanced wind environment from CH86/-, after initially being suppressed. The associated 24-hour fluence is expected is also expected to rise from background levels later on day 2 (Friday 24 March), likely exceeding the Active (1e8 integrated pfu) threshold over the UTC weekend.

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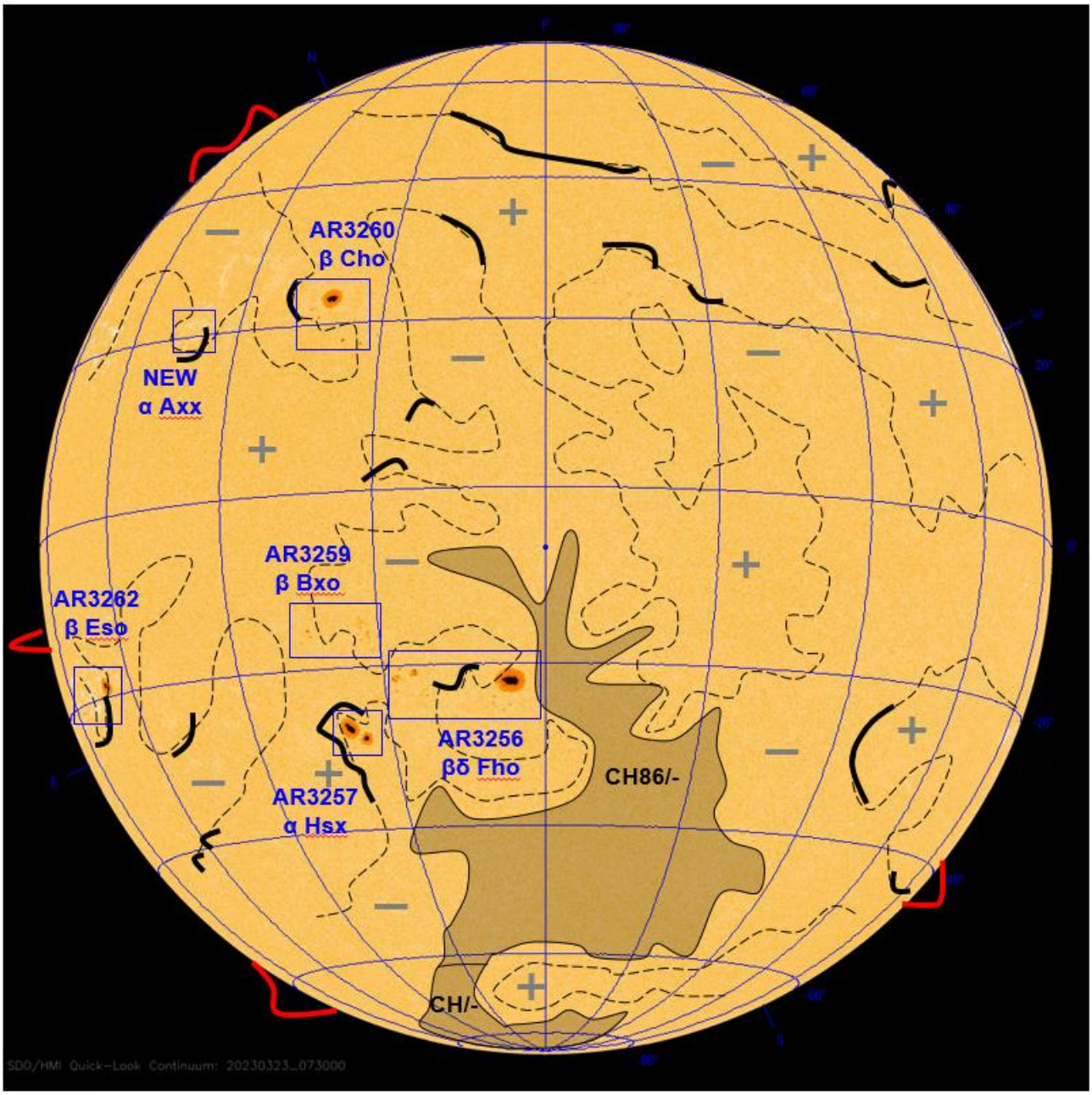
Figure 1. Solar Analysis Valid 23/0730UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are two CMEs that may give a glancing impacts at Earth, however these assessments carry low confidence due to the reduced imagery as a result of both SOHO LASCO and STEREO A having reduced operational availability.

The first was observed on 20 March, leaving the southwestern solar disc as a result of a broad coronal reconfiguration. The signal in coronagraph imagery was weak resulting in low confidence in analysis, but has chance of giving a glancing impact in the immediate term on day 1 (Thursday 23 March). This feature is now overdue based on its most likely arrival time, but therefore carries a risk of being subsumed into the second CME or the CH86/- CIR.

The second CME is from a filament eruption in the northwest disc on 20 March, forecast to reach Earth's orbit around the time of issue of this guidance document. Minimal impact is expected, with much of the material passing north and behind Earth.

Current Slightly Elevated solar winds from CH85/+ should be waning, and indeed had been until the likely transient-derived enhancements of the UTC morning of 23 March began in earnest. Possibly concurrently with CME activity, CH86/- is forecast to become geoeffective later on day 1 (23rd). As a persistent and clearly-defined feature, a Strong enhancement is expected, with winds reaching 600-700 km/s, and likely preceded by a relatively strong CIR region that may now be bolstered by one or possibly two CMEs. Elevated to Strong solar winds are then expected to persist for much of the period, perhaps beginning to ease later in the UTC weekend. During day 1 (23rd), the combined effect of CME arrival(s) and CH86/- enhancement is Likely to increase activity to G1/Minor Storm intervals. There is a Chance of G2/Moderate storms, should these CME and coronal hole sources enhancements align. Enhanced activity is likely to continue into day 2 (Friday 24 March), but gradually easing to mainly Quiet to Unsettled levels from day 3 (Saturday 25 March).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	60	40	10	1
Strong	G3	No	10	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
20/0810	Partial	Coronal dimming	SW	602	23/0100UTC, i.e. overdue.	Miss or subsumed into CIR or 20/1905Z CME.
20/1905	Partial	Filament	NE	815	23/1100UTC	Possibly cause of current enhancement, TBC. Glancing impact most likely.

Figure 2: Latest MOSWOC Enlil and ensemble, showing the pair of 20 March CMEs as bifurcating passes of 1AU in the immediate term. Lowering confidence in the forecast is the apparent absence of any appreciable fast wind enhancment from CH86/-, with is otherwise expected later on day one, Thursday 23 March.

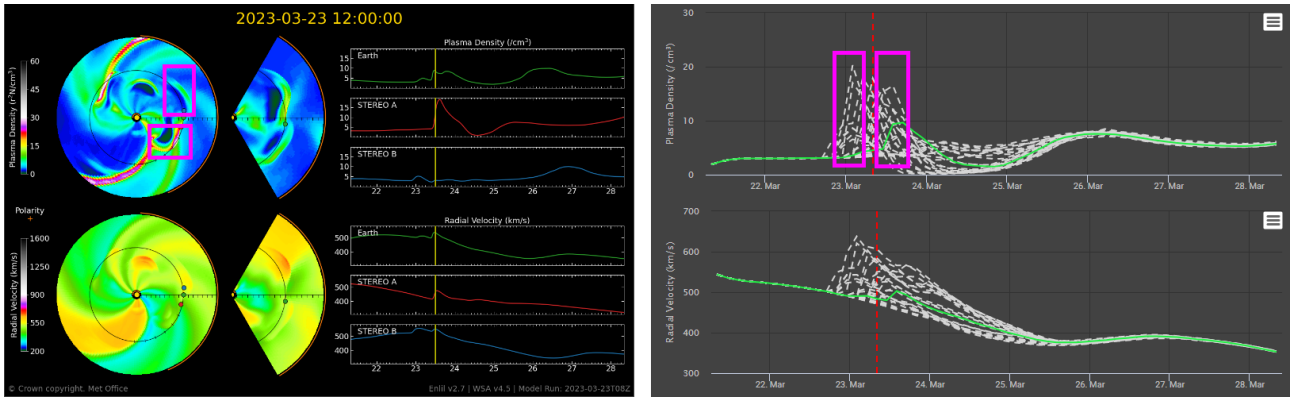
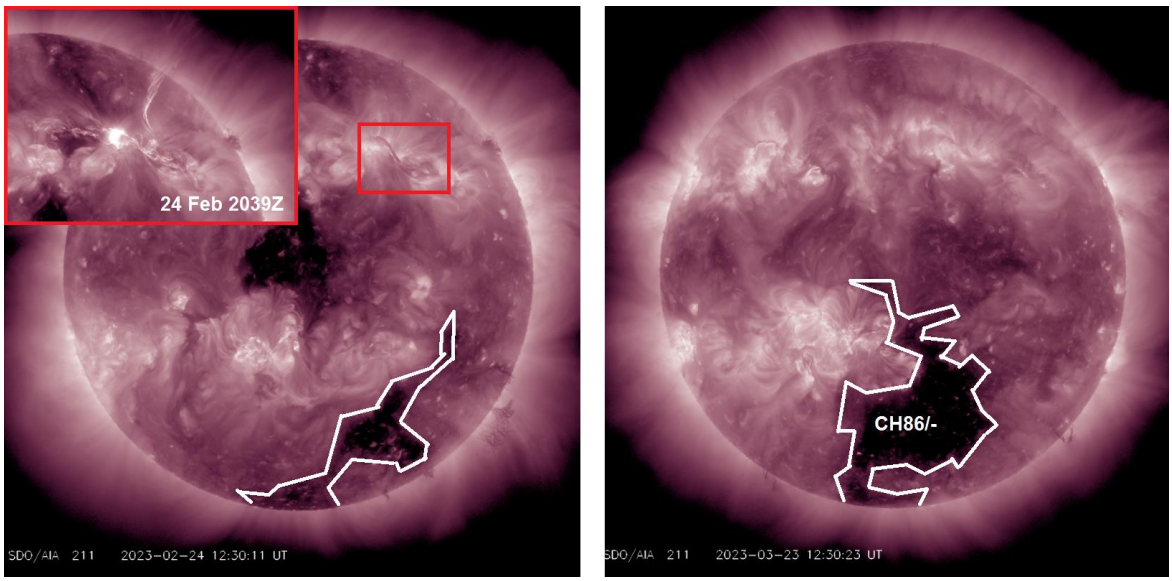


Figure 3: Current and previous rotation in AIA211 imagery, showing changes in geometry of upcoming CH86/-. Also shown is the aftermath of the 24 February filament eruption that would go on to cause a G3 storm at Earth. This event strongly pollutes the geomagnetic indices for the predecessor to CH86/-, swampiong the effect from the coronal hole and lowering confidence as to its effects on this pass.



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Radio Blackouts - X-Ray Flares:

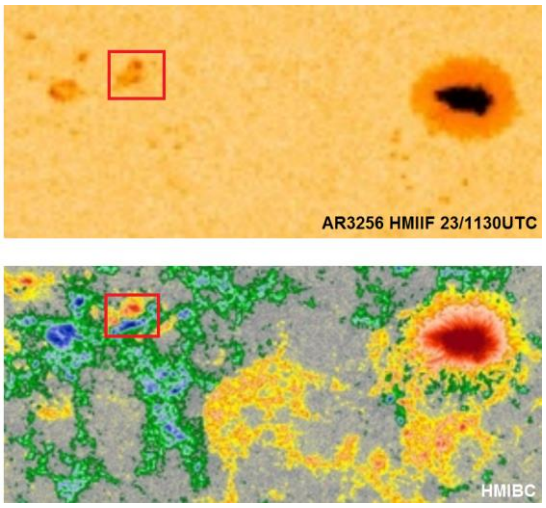
Solar activity is most likely to remain Low through this period, but with a daily Chance of rising to Moderate given the presence of nominally complex sunspot groups on the disc, even if this is not yet being borne out in observed activity.

A proxy for sunspot number - the Penticton 10.7cm flux - had undergone something of a lull around this time last week, however a resurgent eastern solar hemisphere populated by numerous active regions has seen this figure rise day-on-day since 17 March. In terms of sunspot area, the group most responsible for this has been AR3256 near the south centre-disc. This group currently manifests as a 17 degree-spanning Fho Zurich group, and it has recently begun to show a Mt Wilson Delta in its proliferating trailing spots. So, while the current GOES16 X-ray trace is relatively quiet, the above region and also AR3260 (a proliferating Cho/Beta to its north) are perhaps both offering the greatest prospects of M-class activity.

Regarding the trend in flare risk, given the current cohort of sunspot groups occupies the eastern solar hemisphere, none are expected to leave in the four days. The Carrington locations for up to three returning groups lie near the eastern solar horizon, and so the outlook is tentatively for a worsening of the flare risk, however the degree to which this occurs remains to be confirmed as any sunspots arrive.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	25	25	25	25
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 4: Latest HMIIF and HMIBC imagery of sunspot region AR3256, showing the potential Mt Wilson delta spot in its developing trailing portion.



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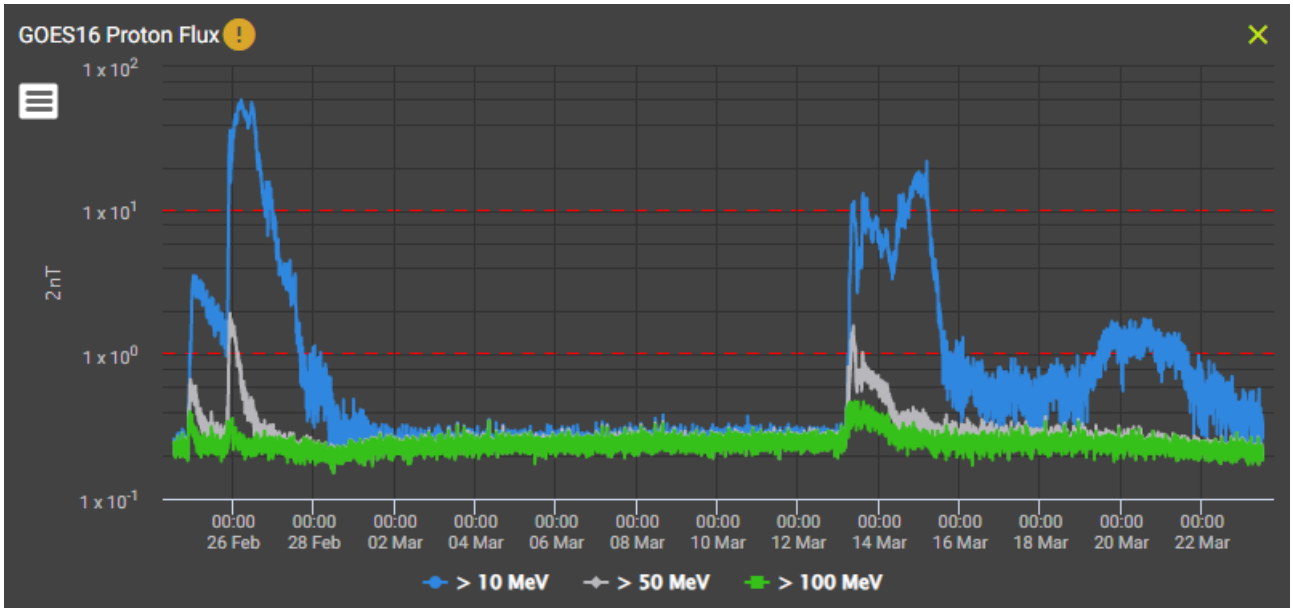
Solar Radiation Storms - (High Energy Protons):

High energy proton flux (greater than 10MeV), as observed by GOES16 is now close to its resting Background level (with 10MeV around 0.5ppcc instead of 0.25).

There is a Slight Chance of further enhancements from a few sources: firstly, one of the larger filaments should they erupt; secondly, an unidentified far-sided region (perhaps the cause of the most recent damped sub-S1 radiation event earlier this week); and thirdly from the sunspot groups in the eastern disc. In terms of the analysable third point - while these groups are not favoured for a strong connection - any significant flares will bring a very slight chance of flux levels rising towards the S1 Minor Radiation storm level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: Past 27 days in GOES16 high energy proton counts. The current trace can be seen to remain marginally above the resting background at 10MeV seen 02-13 March, with current counts roughly double their level in this period, but still substantially sub-S1.



High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2MeV) electron flux observed by GOES16 is expected to become suppressed on day 1 (Thursday 23 March) due to potential CME arrivals and the CIR associated with CH86/-. Flux levels are then likely to rise on day 2 (Friday 24 March) in the enhanced solar wind environment, with the UTC weekend then potentially seeing High levels.

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MOSWOC REFM has a relatively flat 72-hour forecast trend, which is perhaps a little surprising given the magnitude of the expected CH86/- enhancement of 600-700km/s. It is possible that the promontory extending from the bulk of the hole up towards the solar equator was not present to the same degree on last pass, which will have limited CH86's predecessor's potency. Given the initial complication of up to two CMEs in the forecast, REFM is felt to be overly-damped in the forecast period, and a more reactive trace can be expected, even if Active fluence is not eventually realised.

The associated 24-hour fluence is expected to be below the Active (1e8 integrate pfu) level through days 1-2 (the end of the UTC working week). However, fluence levels are expected to rise from day 2 (Friday 24 March) and are likely to exceed the Active threshold over the UTC weekend.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	10	20	60	70
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	5	10

Figure 6: The past week in GOES16 high energy electron flux (top), showing a gradually rising trend in reaction to CH84/+ and CH85/+. The lower plot shows the latest MOSWOC REFM output, with a flat 72-hour forecast trend that is expected to be too low overall and less volatile than observations given the Strong fast wind from CH86/- and the possibility of intervening CMEs.

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